Biology of the Zebra Caterpillar, *Ceramica picta*[1]

(Lepidoptera: Noctuidae)

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In the Yakima valley, several noctuid species, the bertha armyworm, *Mamestra configurata* Walker, the beet armyworm, *Spodoptera exigua* (Hübner), the yellowstriped armyworm, *Spodoptera ornithogalli* (Guenée), and the zebra caterpillar, *Ceramica picta* (Harris), sporadically attack sugarbeets. Of these species, the zebra caterpillar is generally the most damaging, and in late autumn in some years, it so severely defoliates sugarbeets that only the leaf petioles are left above ground. Therefore, from 1967 to 1971, the zebra caterpillar was reared and studied at the Potato, Pea, and Sugarbeet Insects Investigations laboratory at Yakima, Wash., and tests of the sex pheromone of the female were made in cooperation with the Pesticide Chemicals Research Branch (Wallis et al. 1972). In addition, Tamaki et al. (1972) reported life tables which can be used to evaluate the rearing procedure of the zebra caterpillar. The present paper reports details of the life stages to supplement the description of Payne (1918).

MATERIALS AND METHODS

A series of tests was made to determine the reproductive potential, optimum incubation temperature, the number and size of the larval instars, and the duration of instars.

The reproductive potential of the adult female zebra caterpillar was studied by counting the number of oocytes and matured eggs in 25 one-day to six-day-old females. The actual reproduction of the species was estimated by placing 12 pairs in individual oviposition cages and counting the numbers of eggs laid. The cages were 473-ml ice cream cartons lined with paper toweling for ovipositional sites and with wet vermiculite in the bottoms to maintain a high humidity and a cotton wick saturated with 10% sucrose solution for food.

The duration of the incubation of the egg was investigated by taking an egg cluster about 12 hours old from each of four females (laid on paper toweling), separating each into six parts, and placing each part in a ventilated plastic jelly cup. Then four jelly cups (one from

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each cluster) were placed in a glass gallon-size jar and exposed in a temperature control cabinet maintained at 10, 15.6, 21.1, 26.7, 32.2, or 37.8°C. A wire screen stage held the cups above a saturated solution of calcium nitrate salt placed in the bottom of each jar to maintain the relative humidity within a range of 50–70%.

To determine the number of larval instars and the differences in size between instars, we placed several hundred neonate larvae in a tray with sugarbeet leaves and in another tray on Shorey's (1963) bean-based artificial diet (the primary diet used to rear zebra caterpillars in the laboratory). Each treatment was replicated three times. Then 10 randomly selected larvae from each treatment were removed every 12 or 24 hr (rotated between trays), preserved in 70% alcohol, and measured to determine the greatest width of the head capsule and length of body. The head capsules of field-collected zebra caterpillar larvae found on sugarbeets in the autumn were also measured.

The developmental rate of the life stages of the zebra caterpillar was determined by rearing a total of 600 caterpillars (200/treatment) in the laboratory with three procedures. Procedures one and two differed only in that the diet was sugarbeet leaves or Shorey's (1963) artificial diet. Otherwise, 100 neonate larvae per tray were reared with a technique similar to that used for the tobacco hornworm, *Manduca sexta* (L.) (Yamamoto 1969). Thus, the larvae were checked daily for stage of growth, and the trays were cleaned; however, fresh leaves were provided two to three times per week when the larvae were small (changed daily in later instars). Procedure three involved rearing 200 caterpillars singly on about 15 ml of Shorey's diet in 30-ml jelly cups capped with tight lids (no food was added to the cups). All 600 larvae were from one egg cluster from one female and were held in the same room at an average rearing temperature of 25°C (18–28°) with a 16-hr photophase. Then as the last-instar larvae changed to the prepupal stage, the insects were transferred to vermiculite for pupation. Pupae were easily sexed using the characters illustrated by Butt and Cantu (1962) for sexing pupae of other Lepidoptera.

Results

The reproductive system of the female zebra caterpillar contains a pair of ovaries with a total of eight ovarioles. In a newly emerged female, an ovariole is 10–12 cm long and filled with a single strand of oocytes. Egglaying (reproductive) potential determined by dissecting nonparous virgin females showed that the zero- to one-day-old

TABLE 1. Mean hatching time of eggs of *Ceramica picta* held at various constant temperatures (from adults reared on artificial diet), December 1970.

Temperature °C	No. of eggs incubated	No. of eggs hatched	Mean hatching time (days)
38.0	512	0	—
32.2	356	0	—
26.7	294	294	5.0
21.1	279	275	6.2
15.6	388	290	12.3
10.0	365	0	—

females contained no mature eggs (eggs with ribbed rows of chorion were indexed as mature); the two-day-old females had 40% mature eggs; and the three- to six-day-old females had 50–58% mature eggs. In these older females, egg laying had been delayed because fertilized females normally lay their eggs two to three days after emergence. The total number of oocytes plus mature eggs per female in 25 females averaged 1,236 (range 884–1,884). The average number of eggs actually deposited by the 12 mated females in the oviposition cages was 986 (range 59–1,998). Therefore, many females were apparently able to lay their full complement of eggs, but a few laid only a small proportion.

The effects of temperature on the rate of development of eggs of the zebra caterpillar are shown in Table 1. Eggs did not hatch at high temperatures (32.2°C and 38°C), but at 26.7°C, 100% egg hatch occurred within five days, the shortest hatching time; this temperature was therefore designated as optimum. At 21.1°C, 99% hatch occurred, but the incubation time was about 20% longer than at the optimum temperature. At 15.6°C, hatch was still relatively high (75%), but the incubation time was increased by 140% over the optimum. No egg hatch occurred at 10°C.

Payne (1918) reported that the zebra caterpillar had five larval instars in Nova Scotia. However, he presented only a range of measurement for use in separating the instars and gave no average measurements for the width of the head capsules and the length of the bodies. In our studies in eastern Washington, both the laboratory-reared and the field-collected caterpillars had six larval instars (Table 2). However, the range of width of the head capsules of the second instar given by Payne (1918) fell between our measurements for the second and third instars.

TABLE 2. Measurements of *Ceramica picta* reared in the laboratory on sugarbeets and on artificial diet and of field-collected larvae taken from sugarbeets.

In-star	No. and width of head capsule (mm ± SD)						No. and length of larvae (mm ± SD) reared in the laboratory on					
	Reared in laboratory on				Field-collected from sugarbeet		Sugarbeets			Artificial diet		
	Sugarbeets		Artificial diet									
	No.	Width	No.	Width	No.	Width	No.	Length	Range	No.	Length	Range
1	60	0.29 ± .04	83	0.34 ± .05	1	0.33	60	3.68 ± 0.65	2.0–4.5	83	3.64 ± .97	2.2–5.0
2	68	.54 ± .04	53	.58 ± .05	47	.58 ± .08	68	6.01 ± 1.27	4.0–9.0	53	6.75 ± 1.38	4.5–9.5
3	65	.87 ± .06	49	.95 ± .08	110	.89 ± .07	65	10.61 ± 1.82	7.0–14.0	49	11.29 ± 2.30	6.0–15.0
4	57	1.44 ± .07	47	1.50 ± .09	99	1.37 ± .09	57	17.03 ± 2.32	11.0–22.0	47	18.01 ± 3.14	12.0–27.0
5	76	2.12 ± .07	107	2.13 ± .07	61	2.11 ± .12	76	26.82 ± 4.84	17.0–36.0	107	25.91 ± 3.50	17.0–32.0
6	75	3.01 ± .12	85	3.02 ± .09	39	3.07 ± .14	75	37.40 ± 6.33	20.0–50.0	85	39.82 ± 5.01	28.5–50.0

TABLE 3. Pupal weight of male and female *Ceramica picta* reared by three procedures.

Rearing methods	Weight of pupa (mg ± SE) [a]	
	♂	♀
Artificial diet—in cups	496.5 ± 9.08	600.8 ± 15.53
Artificial diet—in tray	481.9 ± 14.63	556.4 ± 25.93
Sugarbeet leaves—in tray	388.3 ± 3.13	434.0 ± 4.15

[a] Standard error (SE).

We found no significant differences in the size of the capsules of the same instar among laboratory-reared larvae fed artificial diet, laboratory-reared larvae fed sugarbeet leaves, or field-collected larvae. However, the measurements for instars did differ significantly for all larvae (Table 2). Also, diet did not cause any significant differences in the length of a given instar, and the differences in length between succeeding larval instars were not statistically significant.

The developmental periods for each life stage of the zebra caterpillar reared in the laboratory on sugarbeets and on artificial diet are illustrated in Fig. 1. At a relatively high rearing temperature (average 25°C), the length of the first to fifth larval stadia reared on sugarbeets ranged from two to five per stage; the sixth stadium averaged about five days though some individual insects took as much as 10 days. The length of the larval stadia for larvae reared on artificial diet in cups was similar to that of larvae reared on sugarbeets, but when the larvae were reared in trays, a few in the later instars had an extended developmental period. Most larval development was completed after 27 days on all diets. Also, except for the decreasing number of insects surviving on artificial diet, no striking differences were evident in the developmental periods of the larval instars when the larvae were reared by the three procedures. In contrast, Tamaki and Weeks (1972) reported that the *Geocoris* ssp. fed an incomplete diet had a prolonged rate of development in the later nymphal instars which was associated with high mortality.

The duration of the prepupal stage was difficult to assess because the cocoons had to be disturbed to check the developmental stage; therefore, checks were infrequent. The average prepupal period was estimated at five days, but a few insects reared on artificial diet in trays had an extended prepupal period (Fig. 1).

The average pupal periods for zebra caterpillars reared on sugarbeet leaves in trays and on artificial diet in trays and in cups were

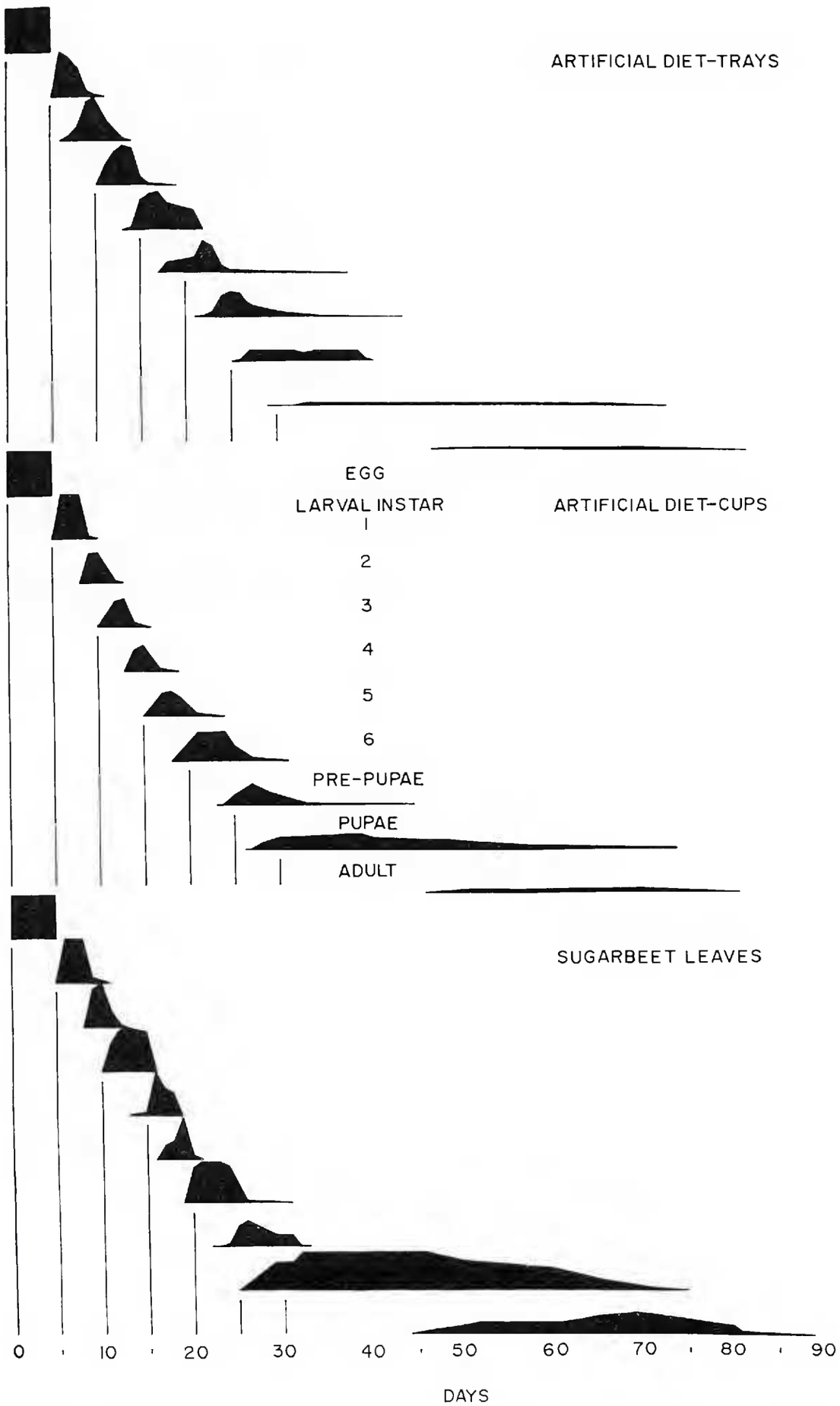

FIG. 1. The developmental periods of all life stages of zebra caterpillars reared on artificial diet and on sugarbeets by three methods.

34 days (range 16–52), 30 days (range 15–40), and 27 days (range 14–41), respectively. Female pupae were heavier than male pupae (Table 3). Pupae from larvae reared on sugarbeet leaves weighed less than pupae from larvae reared on artificial diet, and the heaviest pupae were obtained from larvae grown on artificial diet in cups (these pupae also had the shortest duration of the pupal stage). However, as shown in Fig. 1, the number of moths was much greater when the larvae were reared on sugarbeet leaves than on artificial diet.

The first emergence of adults occurred at 45 days, but the mean time for females to reach maturity by all three rearing procedures ranged from 62 to 67 days. The preoviposition period averaged two days; the oviposition period averaged seven days (though some females had an extended period that lasted as much as 15 days); and the postoviposition period averaged 0–1 day. When the larvae were reared on sugarbeet leaves, the average lifespan of the female was 10.5 days (range 2–19), and that of the male was 12 days (range 2–21).

Literature Cited

Butt, B. A., and E. Cantu. 1962. Sex determination of lepidopterous pupae. USDA ARS 33-75, 7 p.

Payne, H. G. 1918. The zebra caterpillar (*Ceramica picta* Harris). Proc. Entomol. Soc. Nova Scotia 1917, 3: 44–49.

Shorey, H. H. 1963. A simple artificial rearing medium for the cabbage looper. J. Econ. Entomol., 56: 536–7.

Tamaki, G., and R. E. Weeks. 1972. Biology and ecology of two predators, *Geocoris pallens* Stål and *G. bullatus* (Say). USDA Tech. Bull., 1446. 46 p.

Tamaki, G., J. E. Turner, and R. L. Wallis. 1972. Life tables for evaluating the rearing of the zebra caterpillar. J. Econ. Entomol., 65: 1024–7.

Wallis, R. L., L. I. Butler, and L. M. McDonough. 1972. Sex pheromones of the zebra caterpillar: Bioassay and preliminary chemical investigations. J. Econ. Entomol., 65: 945–7.

Yamamoto, R. T. 1969. Mass rearing of the tobacco hornworm. II. Larval rearing and pupation. J. Econ. Entomol., 62: 1427–31.